Comparison of a Targeted Intervention Program Delivered Face-to-Face and by Personal Videoconferencing for Primary and Middle School Students with Mathematical Learning Difficulties

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This paper describes part of a mixed-methods study comparing the effectiveness of an individual, conceptual instruction based, tuition program delivered face-to-face and by personal videoconferencing (PVC) for 30 upper primary and middle school students with mathematical learning difficulties (MLDs). The experimental intervention targeted number sense and fluency with basic facts in mathematics. Results showed significant improvements were achieved in accuracy on basic skills tasks and standardised test results. Implications for students with MLDs living regionally and remotely are discussed.

It is estimated that approximately 20% of school students in Australia have some academic learning difficulties (Graham & Bailey, 2007). Historically, efforts to address learning problems have focused on literacy rather than numeracy (van Kraayenoord & Elkins, 2004). More recently, however, there has been an increased awareness of the importance of improving numeracy standards for all students (e.g. Graham, Bellert, Thomas, & Pegg, 2007).

Following intervention models from the United States and United Kingdom, Australia has employed a three-wave approach to assist students with mathematical learning difficulties (MLDs), comprised of high quality classroom instruction, early intervention programs and provision of support for upper primary and middle school students who require additional assistance on an ongoing basis (Third-wave). First- and Second-wave interventions absorb a high proportion of allocated funding, meaning Third-wave interventions tend to be implemented on an 'ad hoc' basis and rarely have a strong research basis (Elkins, 2007). Access to Third-wave intervention is particularly problematic for students with MLDs living in rural and remote areas of Western Australian (WA) due to a number of factors including: difficulties with attracting and retaining experienced and capable staff in schools located in these areas; few specialist mathematics teachers; and, fewer opportunities for professional development (SiMERR, 2008). The use of personal videoconferencing (PVC) has the potential to increase access to specialist expertise and intervention programs for all students with learning problems in mathematics. The aim of this study was to provide evidence pertaining to the effectiveness of providing specialist support using internet-based ICT.

Theoretical Considerations

Despite exhibiting varied profiles, many students with MLDs share common weaknesses which impede their ability to progress in mathematics (Geary, 2004). Many authors now agree that MLDs are characterised by poor number sense, and/or difficulties with retrieval of basic number facts and use of mathematical procedures (Geary, 2010). Number sense, as defined in recent studies (e.g. Locuniak & Jordan, 2008), seemingly involves impairments in the implicit ability to determine the exact number of small sets of

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objects and understand the effect of adding and subtracting small quantities from such sets, along with deficits in the approximate number system (ANS) that enables the approximation of larger quantities (Wilson & Dehaene, 2007). An impaired number sense interferes with the development of conceptual understandings, that is, understanding the relationships between numbers and patterns inherent in mathematics (Chinn & Ashcroft, 2007). This makes generalisation of learned knowledge to novel problems difficult (Kroesbergen & Van Luit, 2003) and has been linked to problems in mastering higher order mathematical skills (Gersten, Jordan, & Flojo, 2005). It has been suggested that sound number sense is a prerequisite for learning facts and procedures (Woodward, 2006).

Many students with MLDs also have significant difficulty with accurate and rapid retrieval of basic number facts from memory compared to their non-learning disabled peers. These students continue to rely on inefficient counting procedures to solve even single-digit addition problems (Geary, 2004). The memory deficits associated with fact retrieval deficits appear to be extremely complex (Geary, 2010) and may involve one or more of the subcomponents of working memory, depending on the developmental stage of the individual and the specific numerical task (Meyer, Salimpoor, Wu, Geary, & Menon, 2010).

Previous Research

The identification of common deficits has led to evidence-based interventions to address the weaknesses experienced by students with MLDs. Interventions targeting conceptual understandings of number and mental computation skills (French, 2005) have been shown to facilitate number sense growth in primary and middle school-aged students with MLDs. Most studies, however, have involved very young children and can be considered preventative rather than remedial intervention (e.g. Locuniak & Jordan, 2008).

Remedial interventions for improving basic number knowledge for students with MLDs have moved from earlier efforts to improve memorisation of basic facts through extended rote learning to direct instruction (Kroesbergen & Van Luit, 2003), explicit strategy instruction (Powell, Fuchs, Fuchs, Cirino, & Fletcher, 2009), explicit instruction in efficient counting strategies (Fuchs et al., 2009) and deliberate and distributed practice (Fuchs et al., 2010). Rather than rote learning basic facts, it has been suggested that students with MLDs can more effectively achieve fluency in basic skills through developing an understanding of the underlying logical principles, patterns and structures in mathematics (Baroody, 2006; Ginsburg, 1997), although results of a recent study showed no additional benefit in basic fact fluency between drill and practice and explicit conceptual instruction conditions (Powell et al., 2009). Some authors have suggested that effective interventions should focus on the commitment to memory of a small set of key facts, from which other basic facts are derived (Chinn & Ashcroft, 2007). These key facts appear to be most effectively learnt and consolidated using multisensory methods, including the use of concrete manipulatives and visual representations (Butler, Miller, Crehan, Babbitt, & Pierce, 2003) and utilising the 'overlearning' principle (Montague, Warger & Morgan, 2000) for students with MLDs.

In terms of transfer of improvements in basic fact fluency to higher order mathematical skills, Fuchs et al. (2010) reported that only interventions involving strategic counting instruction resulted in corresponding gains in procedural calculations. By contrast, interventions involving drill and practice (Fuchs et al., 2009) and explicit conceptual instruction (Powell et al., 2009) showed no transference of improvements in basic fact fluency to procedural calculations. In these studies none of the interventions targeting basic fact fluency resulted in transference of improvements to word problems.

Conversely, Australian researchers, Graham, Bellert, Thomas, and Pegg (2007) demonstrated that specific intervention targeting efficient strategy use and involving computer-based practice of basic number facts can improve the automaticity of basic skills and performance on standardised testing in middle school students with MLDs. However, this intervention was delivered to students in pairs in live, face-to-face (FtF) situations by trained tutors. No data have been presented on how targeted intervention could be delivered to students requiring specialist help via remote access, or how a remote delivery modality influences the effectiveness of targeted intervention in mathematics.

Research Purpose

In this paper the focus is on two of the aims of a larger study in which the effectiveness of a targeted, conceptual instruction based, individual tuition program, aimed at improving number sense and fluency with basic skills in mathematics for upper primary and middle school students with MLDs was investigated.

The Study

The study utilised a two-phase sequential, mixed method design in which quantitative data were collected to determine: (1) the efficacy of the intervention for yielding improvements in the fluency with basic mathematics facts and any differences in student achievement as a result of PVC compared with FtF tuition; and, (2) performance in higher order mathematics tasks, as evidenced by scores on standardised testing, following the intervention delivered by PVC compared to FtF delivery.

Participants

Thirty students from Years 4 - 9 were selected for participation in the study from an initial cohort identified as requiring specialist intervention by educational psychologists or teachers. The participants were not deemed to be intellectually impaired but had achieved below average numeracy scores in the most recent national testing program, had shown persistent poor performance in school mathematics over a period of one year, and scored below the 35th percentile rank in pre-intervention standardised testing.

Students were assigned to one of two intervention conditions: (1) participants receiving tuition by FtF delivery or (2) participants receiving tuition by PVC delivery. Assignment of participants to particular groups was based on pragmatic considerations similar to those normally influencing the choice of delivery modality; for example, distance between locality of tutor and participant motivation. Participants from both metropolitan and regional locations were included in the PVC group to control for the lower mathematics performances of students in regional and remote schools in WA (e.g., ACARA, 2013).

Pre-Test and Post-Test Assessment Measures

The effect of the intervention on participants' fluency (speed and accuracy) with basic skills was evaluated by comparing pre- and post-test scores using the Cognitive Aptitude Assessment System [CAAS] (Royer & Tronsky, 1998), a software program previously used by Australian researchers (Graham et al., 2007). Response speeds of participants' verbal answers was recorded by the software when the SPACEBAR was activated by the researcher as participants provided responses to stimuli presented on the computer screen.

Each response was then 'marked' for accuracy by the researcher right or left clicking the computer mouse. The same procedures were followed for both intervention groups. CAAS testing was also conducted following the completion of each set of 12 tuition sessions (interim-test scores). Student performances on higher order mathematics skills were evaluated by comparing pre- and post-test performances on the standardised tests: the Progressive Achievement Tests in Mathematics, [PATMaths] 3rd ed. (ACER, 2005) and the online version, PATMaths Plus (ACER, 2010). Test questions were read to participants with comorbid reading difficulties, determined by a clinical diagnosis of dyslexia or participation in a school literacy support program. As participants were in different years of schooling, raw scores were converted to scale scores (expressed in patm units) on the PATMaths Rasch scale, "allow(ing) for comparisons between students, year levels and pre- and posttesting, regardless of the test completed" (ACER, 2010, p. 2). Although the sample size was small, statistical procedures were performed to ascertain the significance of any changes in scores, following other studies involving small numbers of participants (Bellert, 2009; Kaufmann, Handl, & Thony, 2003). Effect sizes were calculated for each assessment measure, and rated from small to large according to Cohen's (1988) criteria, as an indicator of the contribution of the results (Durlak, 2009).

Experimental Intervention

Individual tuition programs, featuring explicit conceptual instruction and differential practice, targeting number sense, efficiency of strategy use, and basic number fact fluency across the four mathematical operations (addition, subtraction, multiplication and division) were implemented with participants in the two experimental groups. Instructional materials for the FtF and PVC groups were similar and included: integer rods and Base-10 blocks, 100-square, number lines, dot-array and digit dice, PC-based visual representations of counter and block arrays, diagrams drawn on whiteboards; timed practice was undertaken using PC-based computer games. The difference in instructional materials between the groups was the use of concrete manipulatives in the FtF group. Wherever possible, interactive whiteboard visual representations of concrete manipulatives were used in place of concrete manipulatives for the PVC groups. Also, participants in the FtF group had control of PC-based games, whereas the tutor assumed control of the games in response to verbal instructions given by the participants in the PVC groups.

The individual tuition programs delivered by PVC and FtF modalities followed the same format. Tuition was delivered to 39 of the students by the researcher, a specialist teacher with 7 years' experience working with students with learning difficulties and disabilities. Tuition was delivered to one student in the FtF group by a graduate teacher where each tuition session was conducted under the direct supervision of the researcher to ensure fidelity of the intervention (Graham et al., 2007). All participant students received a maximum of 24 individual tuition sessions at a frequency of one tuition session per week for the first 12 sessions. The final 12 sessions were conducted at a frequency of two sessions per week. The maximum duration of each session was 45 minutes.

Results

Fluency with Basic Skills – CAAS

To assess the effect of the intervention program on fluency with basic skills, participants' accuracy (Ac) and speed of response (RL) were recorded by the CAAS software on three occasions—prior to the intervention program, after 12 tuition sessions, and at the conclusion of the tuition program—for each of the following tasks: simple addition, simple subtraction, multiplication, division, and triple addition. CAAS scores were compared for the study cohort as a whole (Table 1) and then by intervention group (Figure 1) to assess any differences resulting from delivery modality. Some study participants were unable to complete the multiplication and division tasks at each of the time points due to difficulty with the addition and subtraction tasks and/or incorrect answers on the practice questions. Nonparametric statistical procedures were implemented for analyses of the CAAS scores due to non-normal data distribution—the results are shown in Table 1. Inspection of the CAAS scores showed increased median Ac scores across the three time periods for all tasks except simple addition for which task the median Ac decreased between pre- and interim testing. Friedman Test results revealed increases for the other tasks to be statistically significant (subtraction $\chi 2 = 10.7$, $p < 0.01$; multiplication $\chi 2 = 20.9$, $p < 0.001$; division $\chi 2 = 16.9$, $p < 0.001$; triple addition $\chi 2 = 7.9$, $p < 0.05$). Post-hoc analyses using Wilcoxon Signed Rank Tests showed that participants had made significant gains in subtraction, multiplication, and division Ac even after 12 tuition sessions, with medium effect sizes. After 24 sessions, significant increases in Ac scores were achieved on all tasks except simple addition, with medium and large effect sizes. By contrast, there were no significant improvements in RLs for any of the tasks across the three time points. Hence, while the participants' accuracy with basic skills improved, the speed of their responses remained mostly unchanged.

Table 1

Pre-, Interim- and Post-Test Median Scores by CAAS Task Showing: The Number of Participants Completing Each Task; Percentages of Accurate Answers (Ac); and Median Response Latencies in Seconds (RL) for all Study Participants

Test	Pre-test			Interim			Post-test		
	n[1]	Ac (%)	RL(s)	n	Ac (%)	RL(s)	n	Ac (%)	RL(s)
Addition	30	95.0	4.96	30	94.7	4.80	30	97.5	5.48
Subtraction	30	84.9	5.85	30	89.9[*M]	5.47	30	100.0[*M]	5.29
Multiplication	22	60.0	6.46	26	68.4[*M]	5.69	27	83.8[*L]	4.75
Division	8	48.6[2]	5.63	12	69.4[2*M]	5.22	19	90.7[2*L]	5.48
Triple Add	27	86.7	7.49	29	86.7	7.39	29	100.0[*M]	7.70

[1]Number of participants completing task: Ac recorded as 0 and RLs excluded from analyses if task not completed or if connection was disrupted during test; [2]75th percentile score (Md = 0.0);
[*]Indicates significant change from pre-test score $p < 0.05$
[S,M,L] Indicates effect size: S Small (r = .1), M Medium (r = .3), L Large (r = .5) (Cohen, 1988).

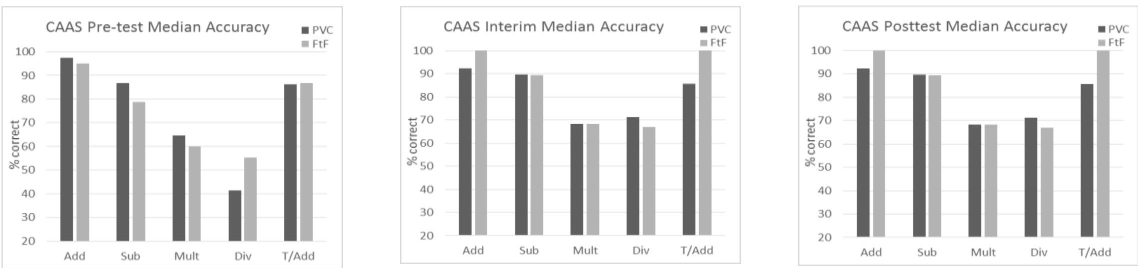

Figure 1. CAAS accuracy scores by intervention group. Division scores for pre- and interim tests are 75th percentile scores as median scores were 0.0.

Fluency with basic skills by intervention group. To ascertain any effects of delivery modality, scores for the intervention groups were examined separately. Friedman test results showed significant improvements in Ac across the three time points for the PVC group on all of the tasks except simple addition (subtraction: $\chi 2 = 6.9$, $p < 0.05$; multiplication: $\chi 2 = 13.3$, $p < 0.01$; division: $\chi 2 = 9.5$, $p < 0.01$; triple addition: $\chi 2 = 6.7$, $p < 0.05$). Conversely, the PVC group showed no significant changes in RLs on any task. By comparison, the FtF group made significant improvements only in multiplication Ac ($\chi 2 = 6.7$, $p < 0.05$) and RL ($\chi 2 = 7.0$, $p < 0.05$) and division RL ($\chi 2 = 7.6$, $p < 0.05$).

Mann-Whitney U Tests results indicated that the only significant differences between the groups at pre-test and post-test were on median RL for addition (pre-:PVC > FtF, $p < 0.05$, $r = 0.39$; post:PVC > FtF, $p <0 .05$, $r = 0.46$).

Performance on Higher Order Mathematics Skills – Standardised Test Scores. To investigate the effect of intervention on participants' performance on more complex mathematical tasks, pre- and post-test standardised test scores for each intervention group were compared. Prior to the intervention, results of an independent groups t-test revealed no significant difference in PATMaths scale scores for the PVC and FtF, $t(2, 28) = -0.37$, $p > 0.05$. The magnitude of the differences in the means (mean difference = 1.40, 95% CI: -9.22 to 6.43) was very small (eta squared = 0.005).

Participants in both intervention groups showed significant increases in standardised test scores after completing the tuition program. Table 2 displays pre- and post-test PATMaths scores for each intervention group. Paired t-tests were used, and for the PVC group, the improvements in scores from pre-test to post-test were statistically significant, $t(2, 19) = 5.10$, $p < 0.001$ (mean increase = 10.71, 95% CI: -15.11 to - 6.31). By comparison, scores for the FtF group also increased significantly from pre-test to post-test, $t (2, 9) = 3.64$, $p < 0.01$ (mean increase = 9.88, 95 CI: -16.02 to –3.74). Eta squared statistics indicated large effect sizes for both groups (PVC = 0.58; FtF = 0.60).

Table 2
Mean Pre-Test and Post-Test PATMaths Scale Scores (in PATM) by Intervention Group

	PVC [a]		FtF [b]	
Time period	Mean	SD	Mean	SD
Pre-test	40.54	8.97	39.14	11.51
Post-test	51.25*	10.18	49.02*	10.75

Note: PVC = Personal videoconferencing tuition group; FtF = Face-to-face tuition group
[a]n = 20, [b] n = 10; *$p \leq .005$

As both intervention groups showed significant increases in PATMaths scores from pre- to post-test, an independent groups t-test was conducted to compare mean post-test scale scores of the groups. Results showed no significant difference in scores for the PVC and FtF groups, $t(2, 28) = 0.55$, $p = 0.58$, two-tailed). The magnitude of the differences in the means (mean difference = 2.23, 95% CI: -10.45 to 6.00) was small (eta squared = 0.011). These findings indicate that for these students with MLDs, a tuition program targeting number sense and basic skills fluency and delivered either FtF or by PVC resulted in significant improvements in performance on higher order mathematics tasks.

Discussion and Conclusion

These results demonstrated that an individual tuition program targeting number sense, conceptual understanding and fluency with basic skills enabled students with MLDs to make significant improvements in their ability to mentally calculate basic mathematical problems accurately. The only task on which participants' accuracy scores did not improve significantly was addition. Less time was spent on teaching and practising addition strategies, as a result of higher pre-test scores, compared with the other basic operations and this may have contributed to the lack of significant improvement in addition accuracy scores. In terms of response times, although the participants did not become significantly faster at responding on any tasks, neither did they become slower as a result of using new mental strategies. These findings support those of other researchers (Baroody, 2006; Graham et al., 2007) and provide further evidence that intervention focussing on conceptual understandings and strategy instruction can be an effective way to improve basic fact fluency for students with MLDS.

Tuition targeting number sense and basic fact fluency resulted in improvements in higher order skills for these participants, evidenced by increased scores on standardised tests. Improvements on higher order mathematical tasks following basic skills intervention were also reported by Graham et al. (2007) but are contradictory to the findings of other researchers (e.g., Powell et al., 2009). Intervention conditions in all of these studies were similar, although participants in those conducted by Powell and colleagues were younger (Grade 3). These findings may have implications for teachers preparing upper primary and middle school students for national testing programs. Rather than 'teaching to the test', that is, spending most instruction time practising sample test items, focusing on basic skills and concepts may be more productive for students with MLDs.

Similar gains were achieved by participants receiving tuition via PVC and in FtF situations suggesting that there is no disadvantage to students if tuition is delivered remotely. The ability to deliver intervention via PVC is highly dependent on the reliability of the technology. In this study, disruptions in internet connectivity were experienced periodically; however, it did not impact negatively on quantitatively measured outcomes.

The results of this small scale study provide initial evidence that specialist intervention delivered by PVC can improve the mathematical performances of students with MLDs. Further research is required to confirm and refine these findings to determine the most effective way of assisting students with MLDs living in regional and remote locations.

References

[ACER] Australian Council for Educational Research. (2005, 2010). *Progressive Achievement Tests in Mathematics*. Melbourne, VIC: ACER Press.

Australian Curriculum, Assessment and Reporting Authority (2013). *National Achievement in Reading, Persuasive Writing, Language Conventions and Numeracy: National Report for 2013*, ACARA, Sydney.

Baroody, A. J. (2006). Why children have difficulties mastering the basic number combinations and how to help them. *Teaching Children Mathematics, 13*, 22-31.

Bellert, A. (2009). Narrowing the gap: A report on the QuickSmart mathematics intervention. *Australian Journal of Learning Disabilities, 14*(2), 171-183.

Butler, F., M., Miller, S., P., Crehan, K., Babbitt, B., & Pierce, T. (2003). Fraction instruction for students with mathematics disabilities: Comparing two teaching sequences. *Learning Disabilities Research & Practice, 18*(2), 99-111.

Chinn, S. J., & Ashcroft, J. R. (2007). *Mathematics for dyslexics including dyscalculia* (3rd ed.). London: Whurr.

Cohen, J. W. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Durlak, J. A. (2009). How to select, calculate and interpret effect sizes. *Journal of Pediatric Psychology*, *34*(9), 917-928.

Elkins, J. (2007). Learning disabilities: Bringing fields and nations together. *Journal of Learning Disabilities, 40*(5), 392-399.

French, D. (2005). Double, double, double. *Mathematics in School, 34*(5), 8-9.

Fuchs, L. S., Powell, S. R., Seethaler, P. M., Cirino, P. T., Fletcher, J. M., Fuchs, D., et al. (2009). Remediating number combination and word problem deficits among students with mathematics difficulties: A randomized control trial. *Journal of Educational Psychology, 101*(3), 561-576.

Fuchs, L. S., Powell, S. R., Seethaler, P. M., Cirino, P. T., Fletcher, J. M., Fuchs, D., et al. (2010). The effects of strategic counting instruction, with and without deliberate practice, on number combination skill among students with mathematics difficulties. *Learning and Individual Differences*, *20*(2), 89-100.

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities, 37*(1), 4-15.

Geary, D. C. (2010). Mathematical disabilities: Reflections on cognitive, neuropsychological, and genetic components. *Learning and Individual Differences, 20*(2), 130-133.

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities, 38*(4), 293-304.

Ginsburg. (1997). Mathematics learning disabilities: A view from developmental psychology. *Journal of Learning Disabilities, 30*(1), 20-33.

Graham, L., & Bailey, J. (2007). Learning disabilities and difficulties: An Australian conspectus - Introduction to the Special Series. *Journal of Learning Disabilities, 40*(5), 386-391.

Graham, L., Bellert, A., Thomas, J., & Pegg, J. (2007). "QuickSmart": A basic academic skills intervention for middle school students with learning difficulties. *Journal of Learning Disabilities, 40*(5), 410-419.

Kaufmann, L., Handl, P., & Thony, B. (2003). Evaluation of a numeracy intervention program focusing on basic numerical knowledge and conceptual knowledge: A pilot study. *Journal of Learning Disabilities*, *36*(6), 564-573.

Kroesbergen, E. H., & Van Luit, J. E. H. (2003). Mathematics interventions for children with special educational needs: A meta-analysis. *Remedial and Special Education, 24*(2), 97-114.

Locuniak, M., & Jordan, N. (2008). Using Kindergarten number sense to predict calculation fluency in Second Grade. *Journal of Learning Disabilities, 41*(5), 451-459.

Meyer, M. L., Salimpoor, V. N., Wu, S. S., Geary, D. C., & Menon, V. (2010). Differential contribution of specific working memory components to mathematics achievement in 2nd and 3rd graders. *Learning and Individual Differences, 20*(2), 101-109.

Montague, M., Warger, C., & Morgan, H. (2000). Solve it! Strategy instruction to improve mathematical problem solving. *Learning Disabilities Research & Practice, 15*, 110-116.

Powell, S. R., Fuchs, L. S., Fuchs, D., Cirino, P. T., & Fletcher, J. M. (2009). Effects of fact retrieval tutoring on Third-Grade students with math difficulties with and without reading difficulties. *Learning Disabilities Research & Practice, 24*(1), 1-11.

Royer, J. M., & Tronsky, L. N. (1998). Addition practice with math disabled students improves subtraction and multiplication performance. *Advances in Learning and Behavioural Disabilities, 12*, 185-217.

[SiMERR] National Centre for Science Information and Communication Technology and Mathematical Education in Rural and Regional Australia. (2008). *An Exceptional Schooling Outcomes Project*. Retrieved 17 May, 2010 from https://www.det.nsw.edu.au/research/currentprojects/aesop.htm.

van Kraayenoord, C., E, & Elkins, J. (2004). Learning difficulties in numeracy in Australia. *Journal of Learning Disabilities, 37*(1), 32-41.

Wilson, A. J., & Dehaene, S. (2007). Number sense and developmental dyscalculia. In D. Coch, G. Dawson, & K. W. Fischer (Eds.), *Human behavior, learning, and the developing brain: Atypical development* (pp. 212-238). New York, NY: Guilford Press.

Woodward, J. (2006). Developing automaticity in multiplication facts: Integrating strategy instruction with timed practice drills. *Learning Disability Quarterly, 29*(4), 269-289.